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Shop Hints for Structural Draftsmen

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Shop Hints for Structural Draftsmen

BY

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SHOP HINTS FOR STRUCTURAL DRAFTSMEN.

By John C. Moses, M. Am. Soc. C. E.

I.—The Draftsman and the Templet Maker.

The manufacture of structural steel work may be divided into the four operations of drafting, templet making, shop work and erection. The draftsman's portion consists in making drawings in accordance with the designs of the engineer for the guidance of the workmen in the remaining operations. As the engineer's designs are frequently incomplete it may also be part of the draftsman's duties to design details of joints, rivet spacing, etc. This part of his work is frequently described and will not be here dwelt on. We wish rather to consider his work as part of the process of manufacture after the design is complete.

This subject is of growing importance. Drafting offices at the present day are not in as close touch with the shops as formerly and most draftsmen have little personal knowledge of shop operations. As a result drawings frequently call for details that could easily have been so modified as to reduce shop costs; but when these drawings reach the shop they have been checked and approved and it is a troublesome matter to make any changes in them. The badly placed rivets are driven by hand, two sets of templets are made where one might have done, the erector cuts off his gussets to get in his bracing,

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etc. Each one has his opinion of the draftsman, but the culprit is not there to see or hear, and the matter is not important enough to lead a busy foreman to enter a formal complaint. The draftsman keeps on copying the same detail for subsequent jobs, and in the aggregate the increase in cost is considerable.

Further, the cost of drawings is to-day a larger part of the total cost of manufacture than it used to be. The draftsman must justify this by making possible a decrease in the other shop operations sufficient to make a reduction in the total cost of manufacture. This requires an understanding of the operations subsequent to his own.

The writer hopes that the hints here given will be useful not only to the draftsmen employed in structural shops, but also to those elsewhere employed, for economy of production is one of the essentials of good engineering.

We will consider first the templet shop and see what the draftsman can do to save expense in that department while still conforming to the engineer's requirements. He should realize first of all that the cost of the templet department is about two-thirds that of the drafting department, and that the two combined may spend as much on a job as is spent in the actual construction in the shop. Any reduction of expense in the templet shop therefore is decidedly worth while.

It takes about as much time to make the templets for a job as it does to make the drawings. The drafting department, however, generally uses up most of the available time and so the templet foreman must put a number of men on the job at once. Therefore each drawing should be made complete in itself. If two or more sheets

can best be laid out by one templet-maker a note on each sheet must say so. The shop bills must be separate for each sheet. General notes giving size of rivets, reaming directions, etc., must appear on each sheet. Identical pieces appearing on different sheets may be given the same name and be referred to on all the corresponding shop bills but one as "old templet, page ——"; when so noted they are passed over by the templet maker and are made by the man having the page not so marked. But all the dimensions must be given on each sheet to enable the connecting parts to be made without looking up any other drawing. When the templets are checked such a one is tried in each place it is to go and the total number wanted placed upon it.

But if the job is put into the shop piecemeal, so that punching will begin before the templets are done, it is often best to name the pieces on each drawing as if they did not appear elsewhere; it will be easier to make the templet over again than to get back the former one and check the new work with it. This case frequently happens in building work. Pieces should not be named alike when this is done, for templet checkers pass a shop-driven stiffener, for instance, if it matches its girder web, and do not try the actual spacing. The templet maker lays out a spacing once and then transfers the marks to the connecting pieces, and so may have them match, although not like the drawing. If the piece appears on another drawing without being noted as an "old templet" it may be made a little differently the second time and not detected. In the shop the stiffeners that match one girder may be put on another web, with poor results.

When parts can not be made identical it is desirable to draw them so that several can be

placed on one templet. This saves lumber, which is expensive, and takes time to prepare; it saves time in making the templets; and it makes less templets to handle in the shop or to store. The similar pieces should be drawn on one sheet; frequently they are represented by one drawing, with notes corresponding to those the templet-maker will use on his templet. In the latter case, do not note a detail as "Omitted on Col. 3 only," but note it thus: "On Cols. 1, 2, 4 and 5." The templet-maker will surround the holes on his templet with a ring containing the numbers 1, 2, 4, 5, and he wants *positive* orders, not negative ones, on his drawing. If similar pieces differ in length by a few inches, throw all the difference into one end, if possible, or else into the two ends, but not into the middle. Then most of the templet holes will be alike for both kinds of pieces. Arrange the holes that are not alike so that they will be at least ⅝-in. apart on the templet; then they can be bored without splitting out the wood between the holes.

Make rivets in girder flanges opposite, and not staggered, if the engineer will allow it. The theoretical advantage of staggering rivets in the two legs of wide angles is, to say the least, problematical, while there is a distinct advantage in placing the rivet on the wide gage of one leg opposite that on the narrow gage of the other leg, since in this case one hole in the templet marks both rivet holes. It should be said, however, that where angles are thick or gages narrow, staggering the rivets makes it easier to drive them; this point is considered much more important in some shops than in others.

In making templets for plate girders a board is first laid off to represent one leg of a flange angle. All odd holes in either leg of any flange angle

are included. Four similar boards are clamped under this one, and then all five are bored at once. Two of them are battened together for the flange plate pattern, and the other two form the top and bottom of the web plate pattern. Similarly a stiffener or web-plate splice is laid out, and with it are bored pieces for the web templet. In order to make this method of templet-making applicable to cambered girders, the camber is produced by making one corner of each web section slightly less than a right angle, keeping top and bottom flanges alike.

For beam work use standard details as far as possible. Boards just large enough to contain the group of holes for each standard connection are kept at the marker's bench, and the beam templet consists of a pole with center lines and names of connections. This pole is laid on the beam, and the connection templets are moved to the proper mark and set at the proper height by gages that hook over the top of the beam and drop into holes in the boards.

Pole templets are strips of wood about 1¼ ins. wide by ½-in. thick, planed on all four sides, and of any desired length. They are also used for angles having single-gage lines, the holes being located by lines drawn across the pole. One side of the pole gives the holes in one leg of the angle and the other side gives the marks for the other leg. When marking the steel the pole is placed alongside the angle, or between two angles, if a right and left pair are wanted, and lines drawn square across the leg of the angle by means of a small try-square. The gage of the holes is determined by a gage on the machine. Pole templets are quickly made, contain little lumber, and can be used several times by planing out the old marks.

Webs of similar truss posts or diagonals can often be made alike when their flanges are different. Templets for such webs are made of two narrow boards battened together. If alike except for distance apart transversely of holes, the boards can be bored from one lay-out and set the proper distance apart when battened together. A small and a large gusset will go on one templet if the holes in one will match the holes in the other as far as they go. It is sometimes advisable to vary the gages in angles from the standard in order to make tie plates and lattice alike.

In planning pieces to go on the same templet it should be remembered that it is not usually best to make templets with detachable ends to be changed for different pieces, or to make them in half lengths to turn over. Templets are made of narrow boards battened together and cannot be turned over to advantage, and detachable parts are apt to be inaccurately matched to the main templet when marking the steel.

The dimensions on drawings are primarily for the templet-maker's use. First of all, he will want to set his helper to work to get out the lumber. For that purpose the drawings should state the length and width of all gussets and lengths of all other pieces. Web splices of girders should be located on a separate dimension line. Locate all web stiffeners similarly, also ends of flange plates. Tie in rivet spacing with other dimension lines at every opportunity. A templet-maker lays out rivet spacing by stretching a tape, usually divided to eighths, beside his board. If he comes out wrong at the end of a long line he has to go all over it again, erasing his old marks; it will save him much time to have his spacing tied in at every stiffener, web splice and

flange plate end. He works with a soft pencil on soft wood, and sixteenths make pretty fine work, to be avoided as much as possible. When a number of equal spaces are used, always give the total they make up. Unfortunately, templet-makers can rarely be brought to see the use of doing anything twice by different methods as a check; rivet spacing on drawings should therefore be checked with general dimensions.

The shop bills should be carefully checked in the drafting-room, for a templet-maker may copy the number of pieces there called for, regardless of the drawing. Write "exact" after dimensions that must not be exceeded. Give the total distance between holes in the outstanding legs of end connection angles, but also give gages in every case for the templet-maker. Note when uprights, fillers or splice battens must be fitted to flange angles. Avoid double cuts on one leg of an angle, as they involve making a special cutting pattern to go with the templet pole.

When showing only part of a given piece, always draw the *left-hand end* of the piece, as the templet-maker must work from left to right with his tape. Use uniform methods, putting general notes in the same part of all drawings, and writing sizes of stock in the same way every time, and on the left ends of the pieces. Do not change existing customs without exceptionally good reasons. Uniformity of drawings not only saves much time when looking for information in the shop, but also much liability of mistake from oversight. In general, remember that the templet-maker has to redraw everything and should have dimensions given so as to make it easy to do this.

There are many advantages in laying out work full size on a floor in the templet shop. Truss

members and connecting gussets are then checked as to length of pieces and matching of holes, and interferences are detected. When this is customary the drawings can be simplified to great advantage and at the same time lessen the work of the templet-maker, who is no longer obliged to follow exact spacings. Many connections can be laid out by him as well as by the draftsman, thus saving the draftsman's time. A disadvantage of this method is the impossibility of dividing the templet work among as many men; another is the lack of the kind of men formerly found in templet shops.

PATTERN MAKING.—Most of this work will consist of shoe plates or machinery for drawbridges. This work is expensive and can often be simplified by making patterns that are altered to make the different castings by means of detachable pieces. Old patterns can often be used again, with perhaps some changes. As usually but one or two pieces of a kind are wanted, it is often cheaper to use an old pattern that is heavier than needed, the cost of a new pattern being more than the value of the iron saved. Cores are expensive to make, and, as shoe plates are designed for bearing values of masonry, the top surface can be ribbed to save metal instead of coring out the inside. Straight surfaces are much cheaper than curved ones, which latter must often be whittled out by hand.

The cost of the pattern rather than the amount of iron is usually the determining factor when there are but few pieces of a kind. The reverse is true when there are many of a kind, and a little calculation of weights and costs will often determine the best thing to do.

Make casting drawings to scale correctly and to a larger scale than is usually used for the other

drawings. Draw them on separate sheets, as they go to the pattern-maker, while the other drawings go to the templet-maker. Note if holes are to be cored or drilled. If the latter, a templet will be made by which to lay out the holes, as on other pieces of iron. Cored holes are likely to be irregular in size and incorrectly located, and should not be used for machinery connections. Always note all surfaces that require planing, as an additional thickness of pattern is there required. A pattern-maker can do almost anything when necessary, but very slight modifications in design will frequently cut the cost in half.

ILLUSTRATIVE EXAMPLE.—As an illustration of some of these hints, the reader is referred to the accompanying drawings (see Plates A and B) showing details of a skew plate girder bridge having a heavy center girder and two lighter outside girders.

Examination of the details will show that all the web templets can be placed on one templet, although the two ends of the light girders are not alike, and the heavy girder has four lines of web holes for each flange in place of two for the light girder. One thing done to accomplish this was to change the end pitch of the light girder from the 2¾-ins. specified by the engineer to 2½-ins., as called for on the heavy girder, it being considered cheaper to drive the few extra rivets required than to make extra templets.

The flange plates are made with lengths to suit the rivet spacing. Those for the heavy girder have rivets farther apart transversely, but this is done by using the templets bored with the flange angle templet, properly spreading them apart when they are battened together. Stiffeners and fillers are spaced to suit the eight lines of flange rivets of the heavy girder. Rivets in the

two legs of a flange angle are placed opposite each other, except where the floor-beam connection requires a different arrangement. The rivet pitch is tied in with the other dimensions, and where a space in sixteenths is necessary it is closely followed by another space with sixteenths that will bring back the total to larger fractions.

The lateral bracing angles are connected with the stringers, but as this bracing will be made on the floor, it is not fully dimensioned, and the stringer holes are left to be determined from the layout. All the stringers will go on one set of templets.

The floor beams are made with all end pieces alike, the difference in length of the two halves being put into the main web and flange angles. As these will be made full length in any case, this is the best place for the variation. Skews for the end frames are given by the original figures. This method involves less risk of mistakes in figuring and is easy to check. If it is acceptable to the templet maker it is the best way.

The draftsman will find that it takes very little extra time to make drawings in this way, and that it will make his work much more interesting to himself as well as more profitable to his employers.

In a subsequent article the writer will consider some of the features of shop operations that should be understood by the draftsman.

II.—The Draftsman and the Bridge-Shop.

In a previous article attention was directed to templet making, and some of the ways were pointed out in which the draftsman could decrease the expense of that part of the process of manufacturing structural work. After the templets are made the steel must be cut, punched, assembled and riveted. In this work, also, it is true that the draftsman can often reduce costs by understanding the methods of the shop and planning the work with these methods in view. Two ways that are equally good from a theoretical point of view may differ widely in point of economy; even where one way is theoretically or aesthetically better than another, the advantage may be gained at a cost that is much greater than the designer would consider himself justified in paying if he knew of it. And sometimes carrying out a theoretically better plan necessitates a kind of shop work that is not as reliable as are the ordinary methods, and the final result is a poorer instead of a better product. The following notes on the principal operations in the shop will show some of the considerations that should govern the draftsman in his work.

SHEARING ANGLES. — Angles are cut to length and to the required bevels at the ends on a special machine having a knife with two cutting edges, one horizontal and one vertical, as shown in diagram by Fig. 1. This knife can cut both legs of an angle at the same time. The whole machine stands on a turntable, and the angles to be cut rest on horizontal skids. Square cuts are made by placing the machine at right angles to

the stock on the skids. In this case the templet need only indicate the length, and the marker draws a square line on the angle with his try-square. A permanent guide line on the machine shows when it is set square to the work. To make bevel cuts, the machine is swung to the bevel given by the templet, or the angles themselves are swung around when not too long or heavy. If a "front cut" (see Fig. 2), the angle is supported by the table of the machine, as in square cuts, but if a "back cut" is wanted the angle must be put into the other side of the knives, on account of the housing, and is generally carried around to the back side instead of turning the machine entirely around. In either case the degree of the bevel is limited by the construction of the machine, as an examination of Fig. 1 will show. For front cuts this bevel varies with the width of the leg cut, and a record of these limits should be in the drafting office. The limiting bevel for back cuts is the same for all sizes.

The bevel cut is made on the horizontal leg of the angle and the vertical leg is left square. If the bevel is a front cut, the angle can be turned over and the other leg also be given a front cut, but one leg cannot have a back cut and the other a front cut, nor can both legs have back cuts.

If bevels outside the limits are necessary, the angle is cut square and then the beveled leg is cut on the plate shear, or else is punched off. This leaves the square leg with a square face. Bevels inside the limit, on the other hand, should be shown as cutting the square leg to a sloping face to save a second cut on the machine.

Fig. 2 shows two ways of drawing an angle for a lateral brace or truss member; the lower sketch shows the angle with square ends, the upper one

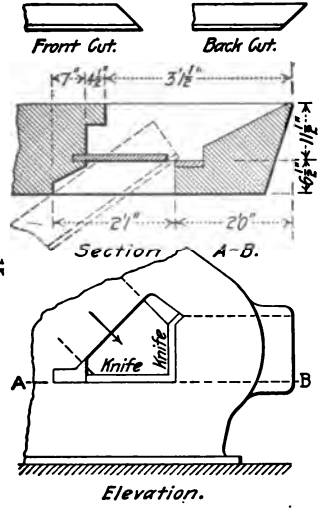


Fig. 1. Capacity Diagram of an 8 × 8-in. Angle Shear, Showing Factors That Determine Limiting Bevel Cuts.

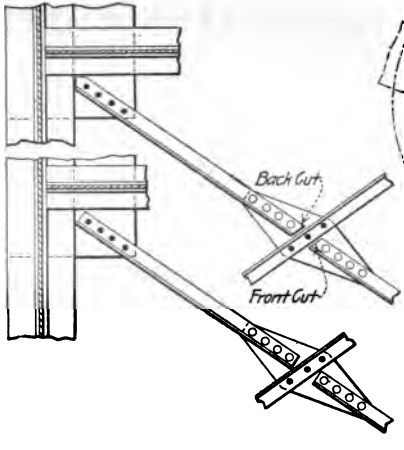


Fig. 2. Two Different Ways of Cutting Ends of Bracing Angles.

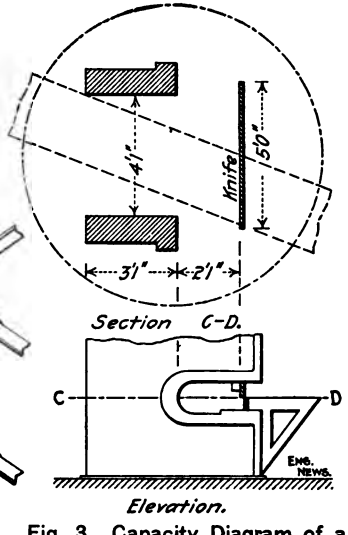


Fig. 3. Capacity Diagram of a 48-in. Plate Shear, Showing Factors That Determine Limiting Bevel Cuts.

the same angle with bevel ends. Where the ends are beveled the operations in cutting the angle in the shop are as follows: A cutting templet must be made for each end in addition to the regular pole, thus doubling the templet work. The angle is first cut square to length, then carried around to the rear of the machine and the back cut made; then to the front of the machine and one front cut made; then turned end for end and the other beveled cut made. If the angle is long or heavy, the machine must be swung for each of these different cuts. Care must also be taken to cut the bevels the correct hand. The economy of cutting angles square will be evident, even if the gusset has to be made larger. The effect on the appearance of the work is much more apparent on the drawing than on the work itself, since the angle leg is flat against a large plate of the same color after painting, and is so much less conspicuous than the outstanding leg that it will not be noticed. In this case, as in many others, the draftsman should frequently examine finished work in order to have a true conception of the result of his drawing.

SHEARING PLATES.—Small gussets are generally cut from large pieces on a shear arranged as shown by Fig. 3. Frequently a number of them can be made with two sides parallel, of the same width; they can then be cut from long plates of that width with few cuts and little waste. When too irregular in shape for this, they should be planned with as few sides as possible, as every side represents a cut of the shear. The size of plate from which they are to be cut should be kept in mind and the gussets planned to use up the material with as little waste as possible. Corners much less than 90° should be

avoided, as the plate will curl when sheared and not fit snugly to the adjoining parts.

Large gussets may be ordered from the mills cut to the shape desired. They are then known as sketch plates, and an extra charge of one-tenth cent a pound is made for them. It is a good plan to figure their cost and compare it with the cost of a rectangular plate of sufficient size, crediting to the latter cost one-half the value of the plate cut off as good material for future work, and the other half at scrap value. The rectangular plate will often be found the cheaper. Plates ordered "sketch" from the mills generally have to be trimmed again on the shears in any case, and are quite often cut wrong or delayed in shipment.

An examination of Fig. 3 will show that long plates to be cut in two on a bevel are limited in position by the frame of the shear. The wider the plate the less the possible deviation from a square cut. This must be kept in mind in ordering stock, and a diagram of the shop shear should be among the draftsman's data.

Reëntrant angles on gussets should be avoided, as they cannot be cut by the shear, but must be punched out. The shear will not cut off a strip of less width than about half the thickness of the metal, and there is, of course, a limit to the thickness it is safe for any given machine to cut.

CUTTING BEAM WORK.—Beams, channels, zees and tees are generally cut in pieces by sawing. This is a much slower and more expensive process than shearing plates and angles, and for that reason it is best to order them to the lengths wanted. They can be trimmed to exact length by the coping machine, which has a heavy square punch for removing portions of flanges, and also shearing knives for cutting the web after the

flanges are removed. Beveled cuts on beams and channels are expensive and troublesome. The smaller sizes of beams and channels can sometimes be beveled in the plane of their webs by first coping off one flange and then cutting the web and other flange on the angle shear. This, of course, means carrying the stock from one machine to the other and handling it twice. Channels that are too large or too sharply beveled for the limits of the angle shear, and beams of all sizes, can have one flange removed by the coper and then have the web sheared to a bevel. This leaves them as at A in Fig. 4, with one

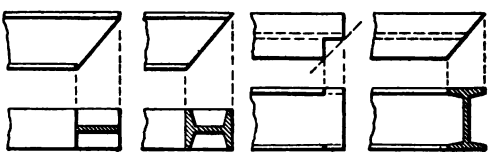


Fig. 4. Different Ways of Beveling Ends of I-Beams and Channels.

flange cut square. This blunt corner will rarely be objectionable, and the draftsman should draw them that way when possible, instead of like sketch B. Beams or channels beveled transversely to their webs are especially objectionable to the shop. Instead of cutting the flanges on a bevel, they can be coped as shown by the sketch C in Fig. 4. When the engineer insists on a sloping cut, as at D, Fig. 4, the shop is driven to heating the end of the beam in a furnace in order to make the cut by hand at a reasonable cost. In most cases this is certainly more objectionable than the sacrifice in appearance where the beam is coped like the illustration. When coping to

obtain clearance in this way it is not necessary to cut off the flange absolutely flush with the web. It is well to say "Cut flush" when this is necessary, and have it understood that an ordinary cut will do in other cases.

LATTICE BARS.—Lattice bars are made by a punch that forms the rounded end and punches the hole on one end of each of two bars at one stroke of the machine, as shown by Fig. 5. A gage is set to give the length and no marking of the iron is necessary. The draftsman should therefore have as few kinds as possible and should avoid any special shape of ends.

FLANGE PLATES.—Girder flange plates are frequently drawn with the corners cut at 45°.

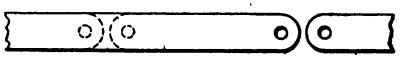


Fig. 5. Method of Cutting and Punching Lattice Bars.

Where double gage lines are used in the angles and the rivet pitch is small, it is necessary to put the end rivets of the flange plates on the inner gage lines and cut the corners to clear the rivets on the outer gage lines. But where the pitch is sufficient a better plan is to have the rivets on the outer gage lines and cut the plates square. This not only saves a large amount of shop labor, but makes it much easier for the track man to frame his ties in the case of a deck railroad girder. As far as looks are concerned, the remarks on shearing angles square instead of beveled are applicable.

STRAIGHTENING.—Long plates have to be straightened edgewise after delivery at the shops. If used for webs of riveted members they should

be narrower than the outside dimensions by ¼ to ½ in. to allow for slight crookedness. Much work on the straightening press will then be saved, as well as probable chipping on the member before the flange plates and gussets can be put on. There will also be less danger of damaging the steel by trying to get out small kinks. Web plates of girders having full length top plates to protect them from water should be ordered *one-half inch* narrow, or they will have to be sheared or chipped in places.

PUNCHING.—When more than one size of holes is called for on a piece, that piece must be handled once for each size, and the cost of punching each time will be practically as great as would be the cost of punching all the holes the same size. This is very nearly true, even if only one hole of a different size is called for. Further, it costs as much to drive a five-eighths rivet as a seven-eighths rivet, and generally more of the smaller size will be required than of the larger. When driving the rivets a change in size means stopping the work to change dies, or else going over the work a second time. Thus, both punching and riveting considerations speak for uniformity in size of holes.

It will generally be cheapest to widen lattice bars that are so narrow as to require smaller rivets than the rest of the work. If some of the holes must be reamed for bolts, make the bolts ⅛-in. larger than the rivets. If more than one size of holes must be used in the job, make the change in the small pieces, as they can be handled easier from one punch to another. Holes for spiking piece bolts and tie rods that are smaller than the rivets used in the connections can be the same size as the rest of the punching, if a washer is used under the nuts. It will often

pay to increase the width of leg of some pieces that are designed with regard only to the stresses, in order to enable the regular size of rivets to be used. Holes larger than the usual maximum allowable in a given size of beam or channel may be put into beam flanges at the ends of the pieces, where section is not required for strength. Slots in webs should be made the same width as the diameter of the punch.

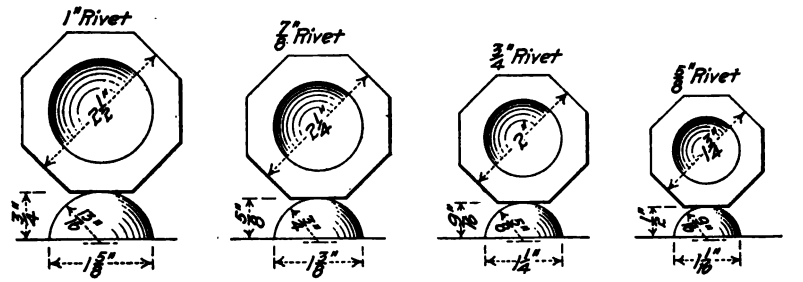
Uniform gages for all holes in the leg of an angle are very desirable. When but one gage line is used the templet consists of a pole that is laid beside the angles, and chalk lines are squared across from the marks on the pole. A gage is set on the punch, and the holes are punched without center punch marks being made. When flat templets are used and the holes marked with a center punch, the use of gages is still advantageous, aiding the men at the punch to do more rapid and accurate work. A hole not on the regular gage, however, must be specially marked and extra care taken to avoid punching it like the regular holes.

Punches are likely to break when of smaller diameter than the thickness of metal punched. Holes should not be put on a joint so as to make half holes in the abutting pieces, as the tit on the punch will force the piece to one side and make a bad hole, besides soon breaking the punch.

ASSEMBLING.—In some shops the men that mark the material for cutting and punching are supplied with the drawings. The templets in this case do not give size of holes, countersinking, allowance for facing, etc., and the markers have to spend considerable of their time studying the drawings, and are high-priced men. Other shops do this work in the templet shop and put all information needed by the marker on the

templet. The drawings are then not use
shop until the punched material is assem
the riveters.
The cost of assembling, or "fitting up,"
greatly with the character or diversity o
work and may be as great as the cost of b
ing. The men engaged in this work want
drawings, with the various plans and elevat
shown in proper relation to each other.
views rather than sections should be given, for
a piece and compare it with the work, but h
man can take his drawing around to the end
cannot see a section without the use of a good
deal of imagination. Top, bottom and end views
should always be placed as shown in Fig. 6, and
not (as is still taught in some schools), with the
top view below and the bottom view above. No
piece at the left of its elevation, and no one else
will that has ever tried to use such a drawing in
the shop. The one exception to this rule is that
the bottom flange of a girder is generally shown
by a sectional plan, and this is done more as a
concession to the draftsman than by wish of the
shop.
Columns are assembled and riveted in a hori-
zontal position and should be drawn in that way.
with the bottom to the left. If drawn vertically
every man in the templet department or shop
will have to turn the drawing around when he
uses it.
Each drawing should have on it a list of all the
complete members shown on the sheet. This
should give the number wanted, name, mar
shipping mark in this way:
Two End Posts wanted, as sho
LoU2R.
Two End Posts wanted, opp
LoU2L.

The foreman checks off against this list as he fits up the work. The list should have a descriptive name for each piece as well as a ship-



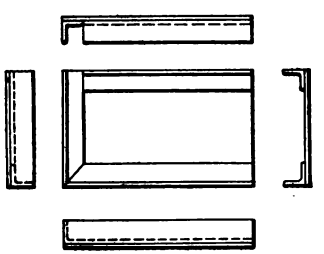


Fig. 6. Proper Arrangement of Views in the Representation of an Object

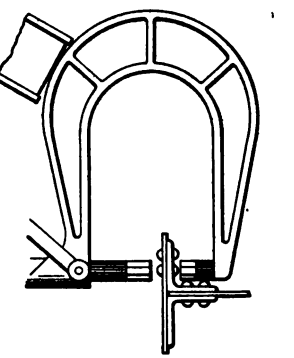


Fig. 7. Sketches Showing Factors Which Determine Minimum Gage in Angles, with Rivets Driven Opposite.

ping mark, and this name should also appear on the shop bills and shipping invoices. All notes should be written in language that is not ambiguous through being too much abbreviated;

notes are often put on in such poor English that they can be read in more than one way.

Open holes, flattened and countersunk rivets should be shown in such a way that they can be marked for the riveters without having to be located by measurements on the iron. The required clear spaces between chords, and the extreme width of entering members should be given directly, and should not have to be obtained by adding up other figures. The distance between open holes on end connections should be given similarly. These distances have to be checked on the iron before riveting is begun; wooden blocks are often bolted into the chords and clamps used on entering members to keep such pieces to the proper width while being riveted up. Note dimensions that must not vary over 1-16-in. as "exact," this being the practical limit of accuracy in structural work. Notes should be given positively, stating that a "Bracket goes on Columns 1, 2, 3, 4 and 6," and not "Omit bracket on Column 5 only." Small sketch views should be used when pieces shown on the same drawing differ much in arrangement of attached parts. It is much cheaper to make them than to have the assembling gang losing time puzzling over complicated notes that are more or less hidden by paint and grease spots, due to handling the drawings and the steel work at the same time.

Center lines, gages, bevels, etc., do not appear on the punched material, and it is often difficult to tell from inspection which way a piece should go. The spacing of the shop rivets can often be made in a way to prevent reversing a gusset or riveting an end connection angle upside down. If the two legs of a connection angle are alike except for a slight difference in gage, the gage of the shop driven leg should be changed to be

either the same as the other leg, or else markedly different from it.

RIVETING.—Shop rivets are generally calculated at higher values than field-driven rivets, it being assumed that they are driven by machine riveters capable of exerting heavy pressure. It is important, therefore, to avoid placing them in positions that cannot be reached by these machines. Rivets that cannot be reached by the machine riveter are left to be driven later by hand at a much greater cost.

Fig. 7 shows the factors determining gages and clearances for such machines when used with full-sized dies. When rivets must be driven on narrow gages the corner of the die is ground away to clear the fillet of the angle. But the rivet head will very likely be forced to one side and not be concentric with the shank, and the dies will soon lose their proper shape and have to be repaired or renewed. For the same reason flange rivets should not be placed too close to stiffener angles or lateral gussets.

Countersunk or flattened rivets require changing dies, and if countersunk rivets have to be flush they must be chipped by hand. When they occur in shoe plates they are generally driven by hand and chipped flush while hot. As they are not required for carrying stresses in such places, their number can often be reduced to advantage.

Draftsmen have been known to place flange plate rivets directly under the outstanding leg of a stiffener, countersinking them in the angle. This practice is very objectionable, for a number of reasons. It involves countersinking the hole, thus removing more metal that was figured on by the designer, and the rivet must, of course, be chipped. The most serious objection, however, has to do with the order in which the

riveting is done. It is customary in plate girder work to first bolt the flange-angles, stiffeners, fillers and splice plates to the web and drive all the rivets whose axes are at right angles to the web. Then the flange-plates are put on and their rivets driven with a different machine. But if the flange-plate rivet comes under a stiffener leg, that stiffener will have to be left off until the flange rivets are driven. Then the girder will have to be taken back to the first machine for driving the stiffener rivets, or they will have to be driven by hand. For the same reason girder stiffeners should not be fitted down on to lateral gussets, but the gussets should be notched around the stiffener.

These examples will serve to illustrate the need of keeping in mind the order of operations in assembling and riveting. When it can be done, members are assembled complete before riveting is begun. Box chords will have their sides driven up first and then the cover plates and lattice added. When pin plates are placed over the web legs of the angles they may interfere with driving the cover plate rivets. Brackets on small columns frequently involve very troublesome riveting, and the draftsman must consider how the shop is going to accomplish what he calls for. Skew connections must often be laid out full size and a rivet of the required length be tried to see if it can be entered into the hole. Rivets in one leg of an angle may have to be countersunk or flattened in order to get rivets into the holes through the other leg. If there is room enough to get a rivet into a hole there is sufficient room so that it can be held on that end, but there must be room on the other end for driving it.

In building work it is frequently possible to so

arrange connections that many of the pieces will have no riveting on them at all. For instance, a beam resting on a column bracket will have a lug on top connecting it to the column. If the lug is attached to the column the beam can go right from the punches to the shipping yard. Knees connecting purlins to trusses can be riveted to the trusses, and the same can be done with the bracing gussets.

BLACKSMITH WORK.—Blacksmith work is very expensive in comparison with the other features of structural work and should consequently be avoided as much as possible. The cost will often depend very much on the amount of duplication. When there are enough bent plates of one kind a special cast-iron die block and follower can be made, and the actual bending done very rapidly, the cost of the die being small in comparison with the saving of labor. When only a few pieces of a kind are wanted the cost per piece may be ten times as great.

Curved end angles for plate girders should be made to fit standard formers and should always be made as separate pieces and spliced to the main flange angles a foot or so beyond the bend. Allow a foot or two of extra stock for each curved piece, as the blacksmith cannot tell just where the curve will come and must trim off the ends after bending. Do not have a bend at each end of a piece, as it is very difficult to get the two bends the right distance apart. The blacksmith will have to work over it so long that the quality of the material may be injured.

Do not call for a sharp bend on a plate if a radius of ½-in. or ¾-in. can be allowed. Besides the additional labor involved, the metal on the outside of the bend will be drawn away and the plate weakened.

Top chords for light roof trusses of small pitch are sometimes made with single lengths of angles bent at the apex. Anything of this kind is a nuisance to handle at the punches, and splicing is generally cheaper in spite of the extra material and rivets required. If such bends are made they should, if possible, be to a radius that will allow them to be bent cold in the press.

III. Shipping and Erection.

SHIPPING.—The maximum size of a single piece that is to be shipped by rail is fixed by the regulations of the roads over which it has to go. Anything not over 8 ft. wide and 40 ft. long can be loaded flat on a single car. Pieces up to 9 ft. wide can be loaded on edge on practically all roads, but if wider pieces are wanted the clearance limits of the roads over which they are to pass must be examined. When pieces are longer than a car, they must rest on bolsters about 6 ins. high, which, of course, use up just that much of the available head room. These limits are based on cars of standard height, and should not be exceeded without investigation.

Roof trusses that it is desired to ship riveted up complete may be so near the available limit that some projecting gusset, purlin lug or splice will cause them to exceed it. They must then be sent in pieces, or else the details must be modified to keep the truss within the proper size. The draftsman will have to balance the cost of riveting in the field against the cost of the same work in the shop with the perhaps more elaborate details. Field riveting requires more rivets and consequently larger gussets. The rivets will cost a good deal more to drive, say 5 cts. each, for field as compared to 2 cts. each for shop. And if any errors are found when assembling in the field they are much more expensive to correct than they would have been if found in the shop. These considerations lead to the general rule to avoid all field riveting possible.

But there is another point to consider in many cases. Railroads charge for at least 30,000 lbs.

of freight per car, and if the actual load is less than this there is a corresponding increase in cost per pound for freight. A job composed of 25,000 or 30,000 lbs. of columns or roof trusses that are 60 ft. long will then cost but half as much for freight if spliced in the field, and this may determine the proper course to pursue. Still smaller jobs, like foot bridges, amounting to three or four thousand pounds, that would require a whole car if their trusses were riveted up in the shop, can be shipped knocked down through the freight office at regular pound rates. If the work has to be teamed from station to site, it will, of course, be easier to handle small pieces.

Long girders are shipped so loaded that they will be pointed the right way when they reach the site. Sometimes, when the proper direction cannot be foretold, it is possible to leave off the shoe plates and thus make the girders themselves reversible. The erector must then rivet on the shoe plates before lowering the girders to place. Projecting gussets or angles on heavy members are liable to injury from having the weight of the member thrown on to them in handling. At least one side of heavy pieces should therefore be free from such projections.

Shipping lists are generally made by the draftsman, and should describe each piece, as well as give its shipping mark. The description should include the principal dimensions, and the items may read as follows:

Two Top Chords, 24 × 36 × 58′ 6″, Marked U2U4.

Four splice Plates, 16 × ⅜ × 2′ 0″, Marked B8.

Etc., etc.

Great care must be taken to have all the separate pieces listed. It costs several days' wages to send by express a splice plate that the draftsman failed to list.

An extra allowance of rivets is required to replace those lost or spoiled in heating and driving; 20% is not too many to send additional, as those not used can be returned with the tools. The erector should be furnished an itemized list, showing where the rivets of different lengths are intended to go. If he finds he needs any different lengths, he will then know at once what to send for and will not run out of sizes unexpectedly.

ERECTION.—Erection work is usually done under far less favorable circumstances than the other parts of the manufacture of a bridge. The men are exposed to the weather, and much of the work is done with temporary appliances that would not be considered adequate in the shop. Frequently an old bridge must be replaced by a new one while traffic is maintained, and the work is largely done at night and in a hurry. Sometimes the falsework is in danger from rising streams, and a few hours' delay may mean the loss of a span worth many thousands of dollars. An error that, if found in the shop, could be easily and cheaply remedied, and perhaps would not even be reported to the drafting room, will become a very costly and serious mistake when found in the field. A heavy truss member will be brought out between trains and after several hours' work be gotten nearly into place when it will be found that the draftsman has overlooked a rivet that should have been countersunk, and the member has to be taken out to get at it. The available time has expired and half a night's work has been wasted. Even if the rivet can be

cut off without taking out the member, most of the gang may have to loaf while it is being done.

The most effective way, then, to reduce erection costs is to realize the seriousness of errors affecting that part of the work. The same reasons that make mistakes so costly make it worth while to plan carefully for the erectors' convenience in every way possible.

The general drawings of the work are designated as "erection plans," and should be complete enough for all ordinary purposes, the detail plans being kept in the tool-box for occasional reference. The erection plans should give the principal dimensions of the work and show the direction to the nearest important railroad station, street names, points of the compass, or some similar means of fixing the way the structure stands. An index of all the drawings should be given on one of the erection plans. The name of every separate piece that appears on the shipping list should be given in its proper place. Erection plans of truss bridges should give extreme height and width, these dimensions being needed to determine size of traveler. The spacing of the floor beams fixes the location of the falsework bents. The clear headroom under portals and bracing and the clear width between trusses should appear; also the distance from masonry to center of end-pin, top of floor beam, or some similar point that will govern the erectors' layout. As a general thing, it is not wise to economize by showing less than the whole length of a bridge span, even when it is symmetrical. For buildings these plans should give grades of all wall and shoe plates, as well as their location from the building lines. Where existing masonry has to be cut away, the plan

should show size and location of holes, in order that they may be cut in advance by the mason.

A system of marking that is used with much success by some companies is as follows: The templet maker always writes his "shop mark" and orders on the left end of his templet, this being always the left end, as shown by the detail drawings. The marks are painted on the steel just as they appear on the templets. The name of each member on the erection plan is placed on the end that is to the left on the detail drawing. The result is that the erector has only to place the "marked end" of his piece to correspond with the mark on his drawing. The same system is followed out on all the pieces that make up a complete member, and is of great assistance in the shop. All templets are sent to the shop with the marked ends together, and as a result all punched material reaches the assembling gang with its marks one way, and the riveted members are sent out of the shop, stored in the yard, and finally shipped with a uniformity that is a help in many ways. In order to make this system still more effective, the draftsman should follow regular rules in drawing truss members, columns, etc., laying them out on his detail drawings with the left hand end as the end nearest the abutment, or by some similar rule. This system of marking is the one used on the drawings of the double track plate girder span that appeared as an illustration with Part I. of this article (see Engineering News of March 22, 1906).

The arrangement of details for greatest economy and convenience in erection requires a knowledge of erection methods that is not common. More money can be made or lost in erection than in any other part of a job. The cost

of the materials and of the drawing, templet and shop labor, the amounts to add for rent, fuel, office expenses and salaries, and the freight to the site, can all be determined in advance with a small percentage of error. The estimated cost of erection is generally a guess that is liable to vary 25% from the final result. This is due in part to unavoidable circumstances and in part to the fact that erection has been left so largely in the hands of the workmen unassisted by the engineering department. An engineer will see where details can be changed to help erection, and yet not injure the structure theoretically, but a foreman cannot go into that side of the question. The present tendency is to remedy this state of affairs by bringing the erection and engineering departments together for mutual advice and assistance. This, of course, is essential on great enterprises, and will undoubtedly be found profitable on all classes of work. It is hoped that others will add to the following hints from their experience.

ERECTION OF BUILDING WORK.—Pedestals and base plates for columns and wall plates for beams and girders should be separate pieces, and the erection plans should give the grades of their top surfaces. They can then be set in advance to accurate grade and location. Columns should be bolted to the pedestals, as they will then need little guying while the beams are being put in place. All columns should be spliced at one level to avoid interfering with the derricks that rest on the floors and are moved up a column length at a time. The splice should be high enough above the floor to admit of riveting after the floor is laid. The splice plates can be riveted to the lower section, but the rivets nearest the end of the section should be omitted

to allow the splice plates to be spread a little. If the vertical distance between the splice plate holes at the joint is made a sixteenth less than the distance between column holes, the sections will be drawn together when pinned up for riveting.

Beams are often connected to columns by resting on brackets, to which they are riveted through their lower flanges. Stiffness is secured by having knees on top of the beams connecting them to the columns. These knees are best shipped loose. They should be drawn with ⅛-in. clearance underneath, as beams nearly always overrun in height on one side, the top and bottom flanges not being square to the webs. When double beams connect to columns or to other beams, parts of their flanges may have to be removed at the ends in order to drive the connecting rivets. Long bolts going through both beams can be used, but are not very satisfactory. If knees are riveted to a beam to receive the web of another beam between them, the drawing should call for a space 1-16-in. greater than the web. A beam having this kind of a connection at both ends is likely to be hard to get in.

Erection plans should show which way the edges of channels turn, the line of the web being dotted in. They should also show the direction of the column webs and the sizes of the beams, as well as their names. All pieces that are identical should have the same mark. If every column has a separate number, the erector will presumably have to overhaul his pile to find the right one when there may be others on top that will do as well. As a matter of fact, he will generally try to find out from his details what ones are alike in order to save himself this

trouble. And in that case he is, of course, likely to make mistakes. Tie-rods should be designated by their length, as they are too small for marking by paint.

ERECTION OF ROOF WORK.—Roofs consisting of trusses connected by bracing or purlins can often be planned to avoid any riveting after the trusses are hoisted in place. The parts of the truss are assembled on the ground and riveted together and the truss hoisted as a whole, the bracing and purlin connections being bolted. If rivets are required, a staging must be built at each joint, and the rivets may cost 25 cts. apiece. One man can put in bolts without any staging, but riveting requires a platform to work on and four men in the gang. Common bolts are perfectly good in many places, and it is good engineering to take advantage of their cheapness in such cases. Turned bolts with a close fit in the holes may sometimes be necessary. If they are expected to supplement rivets in the same joints, they must fit the holes as tightly as the rivets. This will require a taper bolt, and the holes reamed for each one as it is put in. They will be very expensive and of doubtful value, and the draftsman should only call for them as a last resort. Places that are too confined to admit of riveting are generally too confined to admit of the proper reaming for and screwing up of bolts.

ERECTION OF PLATE GIRDER BRIDGES.—Plate girder bridges always have the girders shipped whole. In deck bridges the sway frames should be ⅛-in. less in depth than the space they are to go in. In through bridges having floor beams and stringers the floor may be put in place first and the girders moved in sideways, or the girders may first be placed. If the latter plan is followed, the floor beam connection to the girder

must be planned to allow the beams a movement along the girder that will separate them far enough to get in the stringers. The stringers have to be put in diagonally past the floor beam flanges and then turned straight. The length of the stringer on its longest diagonal should be figured and the possibility of getting it in fully investigated.

One very common difficulty met with in erection is the drilling of the holes in the stone piers for the anchor bolts. This must be done after the steel is in place. The drills should be at least ¼-in. larger than the bolts to make a hole that will admit the cement around the bolt. But draftsmen call for holes in the shoe plates that are just large enough to admit the bolt and place them under gussets and end sway frames, or through the lower angles of stringers, and seem to think the holes will be marked through on to the stone and the bridge removed while the holes are drilled. Consequently, erectors have to chip out the steel to get their drills in on a slant that will bring the top end where they can strike it. The result is a crooked bolt, or frequently no bolt at all. Anchor bolt holes in shoe plates should be ½-in. larger than the bolts and in positions admitting of holding the drills vertical, with room to swing a sledge for striking them. Use a washer under the nut to cover the hole.

Another common oversight is to call for field rivets in the bracing over abutments and piers where the stone is so near that the rivets cannot be entered. In fact, the bracing itself is not infrequently found to interfere.

ERECTION OF HIGHWAY BRIDGES.—The erection plan for a highway bridge should fully show the woodwork for the floor and fence. If

the bridge is on a skew, the ends of the planks at the abutments must be supported in some way. Similarly, wooden fences and wheel guards have to end somewhere, although draftsmen have a way of leaving such matters undetermined. Roadway plank should be planed on one side to obtain an even thickness, and will then measure less than the nominal thickness. Plank that must break joint should be all of one width. Wooden stringers must be sized to less than their nominal depth at the ends to have them alike, and height of shelf angles must be fixed accordingly. Wooden stringers will shrink, and where they are nearly flush on top with steel floor beams some provision must be made for carrying the planking over the beam without resting on it. Spiking pieces on top of beams are best attached by bolts that go entirely through the wood, for lag screws are much harder to use. All lumber to be painted should be ordered planed, and plans should state the number and sizes of nails required. The woodwork of a highway bridge is often the greater part of the erection, and a large item in the total cost of the job.

ERECTION OF TRUSS BRIDGES.—Truss bridges are erected in two general ways. The floor beams and stringers may first be assembled on the falsework and the trusses bolted up to them as they are erected, the floor beams holding the trusses in place until the top bracing is put in; or the trusses may be put in first and the floor afterwards. The draftsman should be informed in advance of the method that will be used.

Most of the remarks already made will apply to truss spans. In addition, the draftsman must provide suitable clearances for posts entering

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into chords and like connections. Built members will vary a little from figured dimensions, being slightly out of square or measuring a little larger when several thicknesses are piled up together. Rivet heads will be higher than figured. Most offices have rules for clearances based on their own experience, but if none such are at hand the draftsman may use the following:

Assume all eyebars and plates used singly as 1-16-in. thicker than figured. Where plates are riveted together, assume each one as 1-32-in. thicker than figured. Assume all countersunk chipped rivets as ⅛-in. high, and all flattened or full-head rivets as 1-16-in. higher than figured. Then add ⅛-in. on each side of a member for clearance as it is put into place.

The portals and overhead sway frames are put in last, and should be arranged to go in without spreading the trusses. It is often a good plan to ship them with the top angles separate. These top angles can then be used for temporary bracing; they leave headroom for the derrick cars, which are coming more and more into use for erection purposes.

Pins are driven into place with pilot nuts temporarily screwed on to the ends. Room must be left to get these nuts off when floor beams or bracing connections come opposite the ends of the pins. Room must be left around pin holes for the nut to turn. When the holes come near the edge of an angle, this often requires a filler to be riveted to the web plate of the chord.

Ends of chords and end posts that bear on pins with half holes should be cut to clear each other by ⅜-in. They should not be faced to bear on each other, when a pin is used, for it is then necessary to bolt them rigidly together before boring the pin hole. This makes trouble in the

shop, especially when the two members make an angle with each other, as at a hip joint. Pin holes are bored with a horizontal boring bar, the members resting on a table or skids.

CONCLUSION.—In the series of articles here concluded the writer has tried to point out to draftsmen the advantage of a knowledge of shop methods and their relative difficulty. The explanations and illustrations given do not exhaust the subject, but will, it is hoped, be of assistance.

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